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ORIGINAL ARTICLE

# Efficacy and possible benefits of using the sit to stand test (5 repetitions or 1 minute) instead of the 6-minute walk test in pulmonary emphysema patients

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**Abstract**

To evaluate which test is more tolerable to exhaled nitric oxide (FeNO) measurements with 5 repetitions of sit to stand test (5 RSTS) and 1-minute sit to stand test (1 MSTS) and 6 MWT in chronic obstructive pulmonary disease (COPD) patients with pulmonary emphysema phenotype. This study included 128 participants with pulmonary emphysema phenotype and 67 healthy participants. 6-minute walking test (6 MWT), 1 MSTS, and 5 RSTS tests were applied to the participants, respectively. Severity of dyspnea (with Modified Borg Scale), heart rate, pulse oxygen saturation ($SpO_2$, by pulse oximetry) during tests. Pulmonary function (with spirometry), quadriceps femoris muscle strength (with manual muscle testing), and FeNO measurements (with Bedfont NObreath) were evaluated. Both STS and 6 MWT outputs were lower in pulmonary emphysema patients than in healthy participants ($p$<0.05). In 6 MWT test, $SPO_2$ decrease, pulse increase, FeNO increase was statistically significant in pulmonary emphysema patients. While 1 MSTS was more sensitive in predicting the sick ones, 5 RSTS was more specific in showing the healthy ones. Both STS create less cardiac and respiratory stress compared to 6 MWT, but also less exercise load. STS are performed in a short time in the outpatient setting in patients with pulmonary emphysema, making it easier to distinguish between the patient and the healthy people, and saves work and time.

**Keywords:** Pulmonary emphysema, exhaled nitric oxide, stand test

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## Introduction

Chronic obstructive pulmonary disease (COPD) encompasses a spectrum of irreversible airway obstructive conditions, including chronic bronchitis, pulmonary emphysema, and obstructive bronchiolitis, rather than representing a single disease entity [1]. Among these conditions, pulmonary emphysema refers to the pathological expansion of air spaces located distal to the terminal bronchioles. The cause of this enlargement is airway wall destruction not accompanied by significant fibrosis [1,2]. The diagnosis of pulmonary emphysema should be considered in anyone with a history of exposure to typical symptoms (cough, expectoration, exercise dyspnea) and disease-specific risk factors (especially smoking), and the diagnosis should be confirmed with appropriate methods [3]. The most important finding of pulmonary emphysema on chest radiography is radiologically low-density areas of reduced vascularization that develop due to damage to alveolar septa and vascular structures. In addition, the most reliable radiologic indicator of hyperinflation in these patients is the flattening of the diagram, and it correlates with the degree of narrowing of the airways [4]. The presence of pulmonary emphysema on imaging techniques and a decrease in diffusion test; usually producing a small amount of sputum, lower body mass index (BMI) than usual, relatively preserved arterial blood gases, and higher dyspnea symptoms compared to the normal population are encountered in the pulmonary emphysema phenotype [5]. Especially in patients with pulmonary emphysema phenotype, peripheral muscle weakness develops together with existing respiratory problems [6]. This is attributed to the fact that pulmonary emphysema extends beyond being a respiratory condition, manifesting as a systemic disorder that includes extrapulmonary manifestations such as muscle impairment, cardiovascular and metabolic complications, and diminished functional capacity. These extrapulmonary effects are also potential risk factors for declining health status and muscle function [7-8]. This leads to a decline in physical functioning and ultimately to a sedentary life.

For these reasons, it is essential to evaluate the functional status of the person in detail in order for the correct medical treatment and pulmonary rehabilitation programs to be effective in patients with pulmonary emphysema [9-11]. For this purpose, different tests are used to determine functional capacity in patients with pulmonary emphysema. Although the 6-minute walk test (6 MWT) is commonly used in contemporary practice to measure functional capacity, its limitations include requiring space, time, effort, and trained staff [12,13]. Therefore, recent studies have recommended using the sit to stand test (STS) as an alternative to the 6 MWT in the elderly and disabled population [14]. Examining the primary rationale behind its recommendation reveals that, for elderly individuals, the ability to rise from or return to a seated position is even more essential than walking. This refers to the condition that enables patients to perform their daily personal activities and is necessary for the onset of these functions [15,16]. The sit-to-stand test (STS) is considered a straightforward and feasible alternative to the 6-minute walk test, as prior research has demonstrated strong correlations between the two in terms of hemodynamic responses and symptom profiles [17,18].

Subsequent research has consistently validated the clinical relevance of measuring exhaled nitric oxide (FeNO) in various respiratory conditions [19]. In addition, studies have shown increased FeNO production after acute and chronic exercise [20-22].

Factors such as corticosteroids, exercise, and smoking reduce fractional FeNO values, while uncontrolled asthma, poor air quality, hay fever, dietary exposures, height, and male sex values increase [23]. Therefore, our study compared five repetitive Sit-to-Stand tests (5 RSTS) and one-minute Sit-to-Stand tests (1 MSTS) with the 6-Minute Walk Test (6 MWT) in patients with pulmonary emphysema. The objective was to evaluate and compare the results of all three tests based on various outcome parameters, including pulmonary function, dyspnea severity, and hemodynamic stress.

The aim of this study is to evaluate whether 5-repetition and 1-minute sit-to-stand tests can serve as practical and valid alternatives to the six-minute walk test (6 MWT) in assessing functional capacity in patients with pulmonary emphysema.

## Materials and Methods

### Study design

This study is a cross-sectional and observational study of COPD patients with pulmonary emphysema phenotype who applied to the chest diseases outpatient clinic of Afyonkarahisar Health Sciences University Hospital between October 2018 and June 2022.

Participants underwent comprehensive evaluations involving respiratory function tests, exercise capacity at both maximal and functional levels, and peripheral muscle strength measurements. In sequence, individuals also underwent two different STS protocols (5 repetitions of STS and 1 minute STS). On the same day, each subject performed STS and 6 MWT at least two intervals. Between each test, randomly assigned using computer-generated random sequences. Respiratory function was evaluated using spirometry, quadriceps femoris (QF) muscle strength was measured through manual muscle testing, and dyspnea severity was assessed via the MMRC scale and the Borg index. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the Afyonkarahisar Health Sciences University Clinical Research Ethics Committee (Decision no: 310, meeting No: 2020/8, date: 03.07.2020, Ethics Committee Code: 2011-KAEK-2), and all participants provided written informed consent prior to enrollment.

### Participants

Patients with COPD with pulmonary pulmonary emphysema phenotype presenting to the pulmonology outpatient clinic for routine check-ups were included. When determining the pulmonary emphysema phenotype, more than one of these tests and criteria were usually used. Clinical findings and criteria were as follows; Chronic cough, sputum production, shortness of breath and exercise intolerance Wheezing on the chest, enlarged rib cage (barrel chest), low body mass index etc Spirimetric test features Those with low Forced Expiratory Volume (FEV1)/Forced Vital Capacity (FVC) values (70% and below) and also patients with decreased FEV1 values From imaging techniques Chest X-ray: Patients with hyperlucency and increased anterior-posterior diameter due to enlarged air spaces in the lungs were included. Computed Tomography (CT). It is a more sensitive imaging method and patients with emphysematous changes in the lungs (such as large air sacs and damage to the lung parenchyma) were included in the study.

Subjects with COPD diagnosed using the Global Initiative for COPD (GOLD) criteria, clinically stable (no exacerbations in the past three months), and who had not engaged in exercise, regular respiratory therapy, or physical rehabilitation in the previous year were eligible [25]. In addition, participants were excluded if they had any severe comorbidities that could impair performance on the tests, such as severe cardiovascular, orthopedic, or neuromuscular conditions, or if they did not complete all assessments for any reason.

The healthy group was randomly selected from among patient relatives or visitors who had standard respiratory capacity as a result of lung function tests (PFT) performed on volunteers. Statistically similar groups were created with the study population in terms of both age and gender.

The extent of the differences in prevalence of COPD between men and women is not well understood and may vary by geography or other factors [26]. In addition, the rate of emphysema in men is many times higher than in women. The reason for this may be that the rate of smoking in men is higher than in women in our region [27]. Therefore, the emphysema patient population in our study consists mostly of male patients.

### Assesment of exercise capacity

### Sit to Stand Test (STS)

Two commonly described STS protocols (5 repetition STS and 1 minute STS) for patients

with pulmonary pulmonary emphysema were selected for comparison between the tests. Subjects were instructed to cross their arms over their chest and perform repeated sit-to-stand movements as quickly as possible during both tests, which were conducted on an armless chair 46 cm high. In the repeated test, subjects performed five movements to stand up and sit down as quickly as possible, and a stopwatch was used to measure the time spent in the activity. In the 1-minute protocol, subjects were instructed to sit to stand as often as possible within one minute. The number of repetitions was recorded [14]. Moreover, since the results of these two protocols were different (time and number of repetitions), the speed (number of repetitions per sec) was considered in the analysis. In addition, heart rate, oxygen saturation ($SpO_2$, palm care plus model pulse oximeter with bionics Co. Ltd, made in Korea), blood pressure, and symptoms of breathlessness and fatigue (modified Borg scale) were measured before and after each test. After five repetitions of the STS test, at least 5 minutes were allowed for rest; after one minute of STS, at least 30 minute rest. Reference values for these two STS tests and the percentage of time or repetitions predicted for all protocols were calculated.

**6-Minute Walk Test (6 MWT)**

The subjects were instructed to walk end-to-end along a 25-meter corridor in the hospital's recreation area. 28 m long, at their own pace, without oxygen support, they were encouraged to cover as much distance as possible in the allotted 6 minutes. A research assistant timed the walk and recorded the distance covered. Then, the research assistant verbally encouraged each subject (Figure 1a). Finally, the total distance traveled at the end of the 6 MWT was recorded to the nearest meter. Dyspnea severity and pulse rate, blood pressure, and pulse oxygen saturation ($SpO_2$, palmcare plus model pulse oximeter with bionics Co. Ltd, made in Korea) were measured before and after the tests. If pre-test $SpO_2$ was below 90%, tests were not performed, and patients were fatigued, the test was terminated according to the tiredness of the legs and/or the severity of shortness of breath, etc., or the subjects' desire to stop.

**Dyspnea assessment**

At a single point in time, the severity of dyspnea at rest and the end of both STS and 6 MWT was assessed with the Modified Borg scale (MBS). The subjects were informed about the use of this scale. In addition, the MBS, the Borg scale rating of perceived exertion, was modified to measure symptoms such as shortness of breath.

**Pulmonary Function Tests (PFTs)**

Spirometry was performed by an expert using a ZAN GPI.3.00 (Germany) device under ATS criteria. Forced vital capacity (FVC), Forced expiratory volume in 1 second ($FEV_1$) and $FEV_1$/FVC values were recorded.

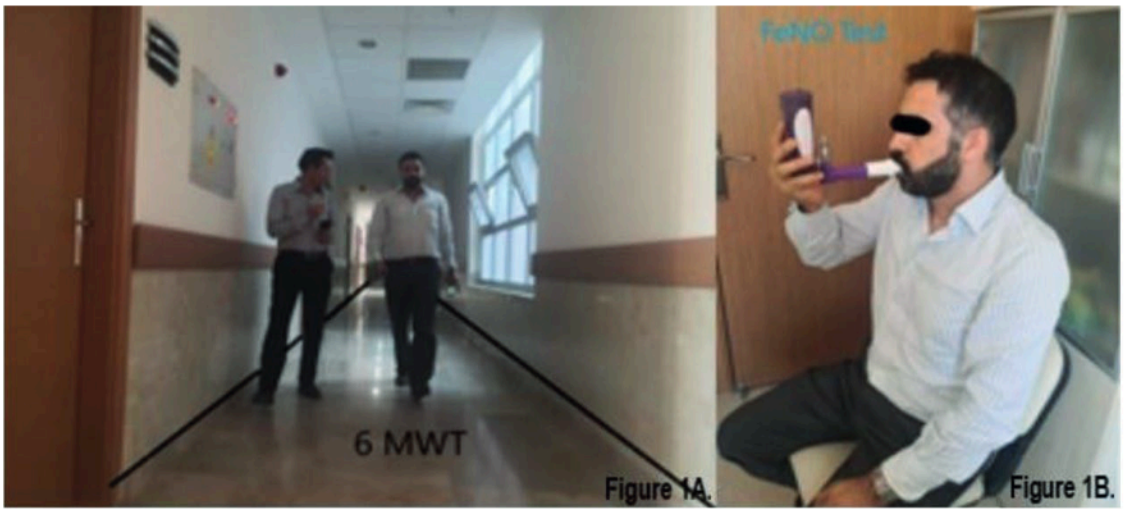



**Figure 1A.** 6 minute-walk test.

**Figure 1B.** Fraksiyone exhaled nitric oxide measurements.

### Peripheral muscle strength

Only QF muscle strength was tested by manual muscle testing in the sitting position using the Daniels 0-5 Rating System. This method used the Daniels 0-5 Rating System, one of the most widely accepted methods of assessing muscle strength, which involves testing the major muscles in the upper and lower extremities against the examiner's resistance and rating the patient's strength accordingly from 0 to 5 [28].

### Nitric oxide measurement

All participants were advised that consumption of nitrate-containing foods such as green salad, caffeinated and alcoholic beverages, and drinking water just before the measurement may temporarily affect the NO measurement. Therefore, the patient should not have eaten or drunk anything at least one hour before the measurement and rinse the mouth before the measurement. Measurements were taken with the Bedfont NObreath (UK) device by using different disposable mouthpieces for each patient, explaining that the patient should first inhale and exhale for 10 - 12 seconds and motivating the patient for continuity during the measurement (Figure 1b).

### Statistical analysis

The SPSS package program was utilized to analyze the acquired data, and descriptive statistics (mean SD) of the variables were provided first. While the t-test was used to determine the significance of differences between the averages of two groups in the analysis of the variables addressed in the study, ANOVA was used to determine the differences between the averages of three or more groups. The Bland-Altman test was used to assess the concordances between the STS and the 6 MWT. Significant differences were indicated as $p<0.05$, $p<0.01$, $p<0.001$ and $p<0.0001$.

Assessed using the Bland-Altman test to evaluate the agreement between the results of STS protocols and the 6 MWT. These outcomes aim to comprehensively evaluate the effectiveness and comparability of the different exercise tests and their correlation with various health parameters in patients with COPD and pulmonary emphysema.

**Study Design Table**

| Step | Description |
|---|---|
| **Study Population** | COPD patients with pulmonary emphysema phenotype; Recruitment: Oct 2018 - Jun 2022 |
| **Initial Assessments** | - Lung Function (Spirometry)<br>- Maximal and Functional Exercise Capacity<br>- Peripheral Muscle Strength (Manual Muscle Testing) |
| **Sit-to-Stand (STS) Protocols** | - 5 Repetitive Sit-to-Stand (5 RSTS)<br>- One Minute Sit-to-Stand (1 MSTS) |
| **6-Minute Walk Test (6 MWT)** | Perform STS and 6 MWT at least twice on the same day; Randomize the order of tests |
| **Outcome Measures** | - Pulmonary Function (Spirometry)<br>- QF Muscle Strength (Manual Testing)<br>- Dyspnea (MMRC Scale, Board Index)<br>- Hemodynamic Stress |
| **Ethical Considerations** | - Conducted according to Declaration of Helsinki principles<br>- Approved by Medical Ethics Committee<br>- Written Informed Consent |

## Results

In the study, there were 114 male and 14 female patients in the pulmonary emphysema group and 52 male and 12 female patients in the healthy group. There was no significant difference in demographic data between the patients with pulmonary emphysema (n=128) and the healthy group (n=67) ($p$>0.05). In addition, similar results were obtained when evaluated in terms of male and female gender ($p$>0.05). However, PFT values were lower in patients with pulmonary emphysema than in healthy individuals and the distribution of smoking history between the COPD group and the healthy group was statistically significant (*$p$<0.05, Table 1).

The results of 1 MSTS and 5 RSTS and 6 MWT distance were significantly lower in patients with pulmonary emphysema than in healthy subjects ($p$⩽0.01), respectively). It was also evaluated that QF muscle strength was lower for right and left QF in patients with pulmonary emphysema ($p$<0.05). In all three tests, there was a statistically significant difference in dyspnea severity before and after the commencement of the test ($p$=0.01). Even though there was no statistically significant change in heart rate or SPO2 at baseline in all three tests, there was a statistically significant difference in SPO2 and pulse rate after 6 MWT. This difference was not seen after both STS tests ($p$<0.01). In addition, when (FeNO) measurements were evaluated and a single FeNO measurement was taken as the baseline within the three tests, a statistically significant difference was observed in different FeNO measurements taken at the end of each test between pulmonary emphysema and healthy subjects after 6 MWT ($p$=0.039, Table 2).

**Table 1**. Pulmonary function test and demographic values between pulmonary emphysema and healthy group.

| | **Pulmonary emphysema group (128)** | | **Healthy group (67)** | | |
|---|---|---|---|---|---|
| | **mean** | **std** | **mean** | **std** | ***p*** |
| Age (years) | 60.96 | 11.64 | 57.27 | 13.51 | 0.06 |
| Height (cm) | 169.86 | 7.18 | 167.78 | 7.79 | 0.078 |
| Weight (kg) | 77.43 | 15.91 | 79.82 | 14.70 | 0.308 |
| BMI (kg/cm$^2$) | 26.82 | 5.38 | 28.37 | 5.24 | 0.055 |
| FVC (l/sec) | 2.35 | 0.82 | 2.70 | 1.05 | 0.013* |
| FVC (%) | 62.74 | 21.42 | 71.36 | 27.31 | 0.016* |
| $FEV_1$ ($_l$ /sec) | 1.40 | 0.64 | 2.70 | 1.61 | 0.003* |
| $FEV_1$ (%) | 46.09 | 17.36 | 80.11 | 22.53 | ⩽0.01* |
| $FEV_1$ / FVC | 58.38 | 9.33 | 85.99 | 8.50 | ⩽0.01* |
| FEF25-75 | 1.20 | 4.36 | 4.14 | 10.48 | <0.006* |
| Smoking (years) | 43.77 | 25.01 | 19.25 | 27.32 | ⩽0.01* |

*std: standard deviation, BMI: body mass index, FVC: forced vital capacity, FEV1: forced expiratory volume in 1 second, FEF 25-75: forced expiratory flow*

**Table 2.** Results of some parameters of pulmonary emphysema and healthy groups after STS tests and 6 MWT.

| | | Pulmonary emphysema group (128) | | Healthy group (67) | | |
|---|---|---|---|---|---|---|
| | | **Mean** | **std** | **Mean** | **std** | ***p*** |
| 1 MSTS (min) | | 18.03 | 4.85 | 20.72 | 5.61 | *0.001 |
| 5 RSTS (sec) | | 16.55 | 4.21 | 14.91 | 3.15 | *0.005 |
| 6 MWT (mt) | | 375.86 | 130.56 | 461.24 | 111.24 | *⩽0.01 |
| MMRC | | 0.98 | 0.94 | 0.61 | 0.79 | *0.007 |
| QF strength (Daniels 0-5 Rating System) | Right | 4.50 | 0.64 | 4.76 | 0.52 | *0.003 |
| | Left | 4.51 | 0.62 | 4.78 | 0.51 | *0.005 |
| Bord index (6 MWT) (mt) | Baseline value | 1.78 | 0.73 | 1.25 | 0.53 | *⩽0.01 |
| | Final value | 3.54 | 0.97 | 2.24 | 0.90 | *⩽0.01 |
| Bord index (5 RSTS) (sec) | Baseline value | 1.78 | 0.73 | 1.25 | 0.53 | *⩽0.01 |
| | Final value | 2.90 | 0.83 | 1.70 | 0.92 | *⩽0.01 |
| Bord index (1 MSTS) (min) | Baseline value | 1.77 | 0.73 | 1.25 | 0.53 | *⩽0.01 |
| | Final value | 2.31 | 0.95 | 2.15 | 0.60 | *⩽0.01 |
| Saturation (6 MWT) (mt) | Baseline value | 93.93 | 4.80 | 93.39 | 2.48 | 0.389 |
| | Final value | 89.09 | 4.78 | 91.06 | 4.78 | *0.025 |
| Saturation (5 RSTS) (sec) | Baseline value | 95.43 | 4.67 | 94.88 | 1.86 | 0.350 |
| | Final value | 90.64 | 6.80 | 90.58 | 5.39 | 0.951 |
| Saturation (1 MSTS) (min) | Baseline value | 94.51 | 4.64 | 94.09 | 1.79 | 0.479 |
| | Final value | 89.95 | 7.36 | 89.58 | 4.51 | 0.707 |
| Pulse (6 MWT) (mt) | Baseline value | 95.84 | 15.83 | 98.36 | 19.86 | 0.337 |
| | Final value | 126.42 | 17.50 | 112.85 | 17.96 | *⩽0.01 |
| Pulse (5 RSTS) (sec) | Baseline value | 92.49 | 15.97 | 96.10 | 19.39 | 0.166 |
| | Final value | 121.34 | 19.01 | 118.39 | 22.51 | 0.336 |
| Pulse (1 MSTS) (min) | Baseline value | 94.63 | 16.63 | 98.40 | 19.57 | 0.159 |
| | Final value | 120.59 | 19.81 | 117.57 | 18.40 | 0.302 |
| FeNO (6 MWT) (mt) | Baseline value | 20.23 | 7.22 | 18.85 | 6.63 | 0.193 |
| | Final value | 22.01 | 7.39 | 19.75 | 6.82 | 0.039 |
| FeNO (5 RSTS) (sec) | Baseline value | 20.23 | 7.22 | 18.85 | 6.63 | 0.193 |
| | Final value | 21.75 | 7.20 | 19.31 | 6.49 | 0.021 |
| FeNO (1MSTS) (min) | Baseline value | 20.23 | 7.22 | 18.85 | 6.63 | 0.193 |
| | Final value | 21.68 | 7.24 | 19.28 | 6.75 | *0.023 |

*std: standard deviation, FeNO: Fraksiyone Exhaled Nitrik oksit, BMI: body mass index, $SpO_2$: pulsed oxygen saturation, 1 MSTS: 1 minute sit to stand test, 5 RSTS: 5 repetitions of sit to stand test, 6 MWT: 6 minute walking test, MMRC: Modified Medical Research Council*

When the STS and 6 MWT results were examined, the correlations of 1 MSTS, five times 5 RSTS, and 6 MWT results in both groups were examined and shown in Figure 2. When Figure 2 is examined, when pulmonary emphysema patients are considered, a significant positive correlation was observed between 6 MWT and 1 MSTS, while a significant negative correlation was found between 5 RSTS. Furthermore, a substantial negative association was discovered between 5 RSTS and 1 MSTS.

When patients with pulmonary emphysema were evaluated according to the GOLD classification, 36 (28.1%) were GOLD A, 23 (18%) were GOLD B, 36 (28.1%) were GOLD C, 33 (25.8%) were GOLD D, respectively.

Furthermore, no significant association was detected when the correlations of all three tests were assessed for the healthy group.

There was no correlation between the three tests and baseline FeNO parameters in both groups. ($p$>0.05) However, a significant correlation was observed for End FeNO in the 6-minute walk test (r=-202, 0.05 ≥ $p$>0.01). When age, BMI (body mass index), and PFT (pulmonary function test) parameters were evaluated, no significant relationship was observed in both groups regarding all three tests. The correlation analysis

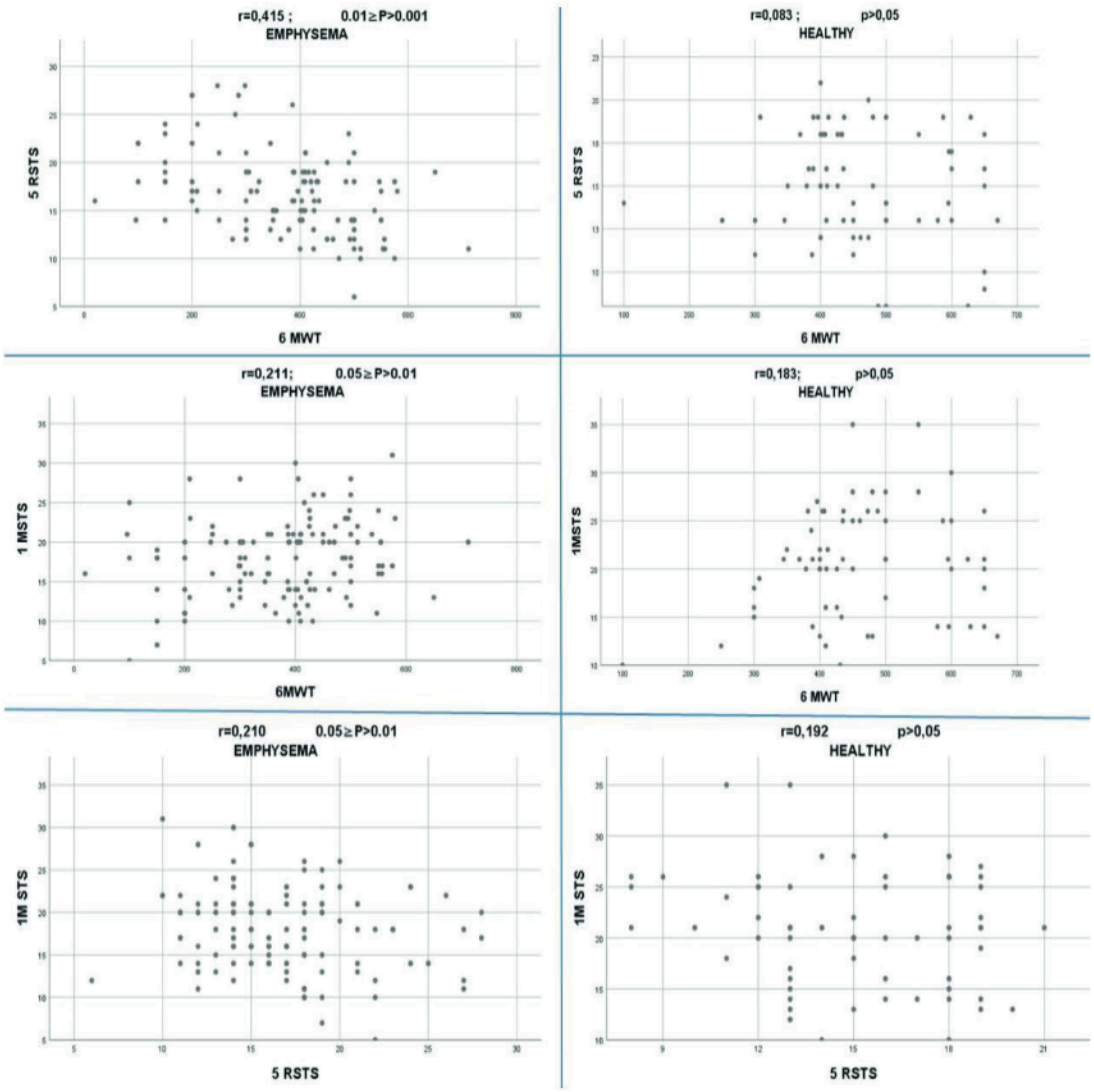



**Figure 2.** Relationship between the 6 MWT distance and the result of STS in healthy and pulmonary emphysema groups.

*1 MSTS: 1-minute sit to stand test; 5 RSTS: 5 repetitions of sit to stand test; 6 MWT: 6-minute walking test of different parameters is shown in Table 3.*

5 RSTS, 1 MSTS, and 6 MWD were first statistically standardized, then their compatibility with the bland atman test was examined. The results obtained are given in Figure 2. When Figure 3 is examined, it can be statistically said that the average differences between 6 MWT and 5 RSTS, 6 MWT and 1 MSTS, 5 RSTS and 1 MSTS are concentrated around zero. Since the average differences are within the 95% confidence limits, it can be statistically said that they will be alternative methods.

Bland-Altman plots of the difference between protocols of 6 MWT mean values plotted against the mean value of STS tests: 5 RSTS – 6 MWD (Figure 3A), 1 MSTS – 6 MWD (Figure 3B) and 1 MSTS – 5 RSTS (Figure 3B). The outer dotted lines show the upper and lower bounds of the agreement, and the middle dotted lines show the

**Table 3**. Relationship between the results of STS and 6 MWT and some outcome parameters.

| | 6 MWT | | 5 RSTS | | 1 MSTS | |
|---|---|---|---|---|---|---|
| | **Pulmonary emphysema r** | **Healthy r** | **Pulmonary emphysema r** | **Healthy r** | **Pulmonary emphysema r** | **Healthy r** |
| FeNO (ppm) | | | | | | |
| Baseline value | -0.14 | -0.11 | *0.03 | *-0.01 | -0.11 | *0.01 |
| Final value | -0.20* | -0.14 | 0.06 | *-0.02 | -0.11 | *0.03 |
| $SpO_2$ | | | | | | |
| Baseline value (%) | 0.42 | 0.10 | *-0.09 | -0.12 | 0.16 | 0.19 |
| Final value (%) | 0.25** | -0.09 | *-0.09 | 0.08 | 0.09 | *-0.01 |
| heart rate (beats/min) | | | | | | |
| Baseline value | *0.04 | *-0.05 | 0.08 | *-0.02 | 0.09 | 0.19 |
| Final value | 0.08 | *0.01 | *0.02 | *-0.01 | 0.19* | 0.32** |
| Borg index | | | | | | |
| Baseline dyspnea | -0.47** | -0.50** | 0.19* | *0.05 | -0.27** | -0.23 |
| End dyspnea | -0.36** | -0.38** | 0.18* | *-0.04 | -0.28** | -0.19 |
| Strength of QF muscle | | | | | | |
| left | -0.07 | 0.27* | 0.07 | 0.09 | *-0.04 | 0.26* |
| right | -0.09 | 0.23 | 0.10 | 0.18 | *-0.05 | 0.27* |
| Age (years) | *-0.02 | *-0.02 | -0.09 | *-0.05 | *0.04 | 0.11 |
| BMI ($kg/cm^2$) | *0.05 | -0.09 | -0.14 | *-0.03 | 0.06 | 0.08 |
| FVC (%) | *-0.02 | 0.14 | *0.01 | 0.23 | 0.08 | -0.18 |
| $FEV_1$ (%) | *0.02 | 0.17 | -0.11 | 0.13 | 0.12 | *0.01 |
| $FEV_1/FVC$ | 0.14 | 0.18 | -0.29 | *-0.05 | *0.06 | 0.14 |

*r: Pearson's and Spearman's rank correlation coefficient, FeNO: Fraksiyone Exhaled Nitrik oksit, BMI: body mass index, FVC: forced vital capacity $FEV_1$: forced expiratory volume in 1 second, PMC of NHPS: physical mobility category of Nottingham health profile survey, QF: quadriceps femoris, Systolic BP: systolic blood pressure, $SpO_2$: pulsed oxygen saturation, * : p< 0.05, ** : p<0.01, *** : p<0.001.*

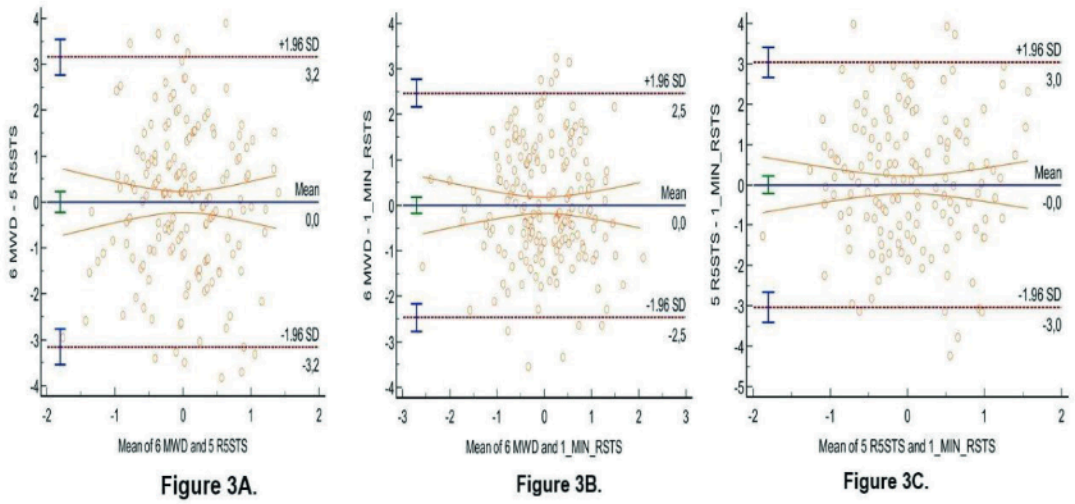
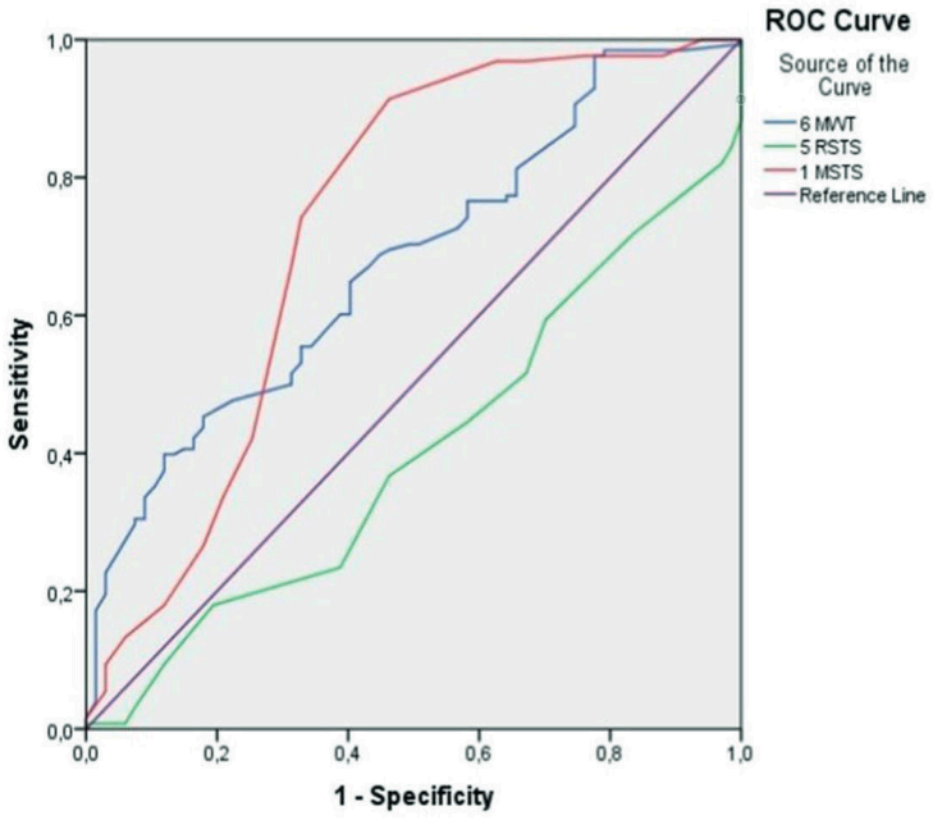



**Figure 3.** Bland-Altman plot analysis.

*1 Min RSTS: 1 Minute of sit to stand test; 5 RSTS: 5 repetitions of sit to stand test;6 MWT: 6-minute walking test.*




| Risk faktör | AUC (%95) | cut of | p | sensitivity (%) | specisfity (%) |
|---|---|---|---|---|---|
| 6 MWT | 0.676 (0.599 - 0.753) | 418.0 | 0.000 | 60.9 | 59.7 |
| 5 RSTS | 0.401 (0.320 - 0.482) | 15.5 | 0.024 | 58.2 | 61.8 |
| 1 MSTS | 0.728( 0.644- 0.812 ) | 18.5 | 0.000 | 67.2 | 51.3 |

**Figure 4.** Comparative ROC plot of all three tests.

*6 MWT: 6-minute walking test; 5 RSTS: 5 repetitions of sit to stand test;1 MSTS: 1 minute sit to stand test.*

average value. Intra-class correlation coefficient $p<0.001$ for all.

Looking at the ROC graph, the 1 MSTS test was more sensitive in determining pulmonary emphysema capacity. In contrast, the 5 RSTS was more specific in showing healthy people and was statistically significant (Figure 4).

## Discussion

The aim of the study is to evaluate whether the combination of 1 MSTS and 5 RSTS with FeNO, $SPO_2$ etc. instead of 6 DYT is more applicable, practical and easy to use compared to the 6 DYT test, since it does not require technician support in an outpatient clinic environment and is performed using a simple chair, in the evaluation of functional capacity in patients with pulmonary emphysema.

In the literature, The 1-minute sit-to-stand test (1 MSTS) and the 5-repetition sit-to-stand test (5 RSTS) are commonly employed to evaluate functional capacity in individuals with orthopedic limitations, particularly among the elderly or those with disabilities [16,29]. The study by Puhan MA et al. in the respiratory field showed the reliability and sensitivity of the 5 RSTS test, while the 1 MSTS test is an indicator of mortality in patients with pulmonary emphysema [30].

The six-minute walk test (6 MWT) is widely utilized in pulmonology practice to evaluate functional capacity and monitor disease progression in patients diagnosed with respiratory conditions, including pulmonary emphysema and interstitial lung diseases [6]. In this study, in parallel with the studies in the literature, the 1 MSTS test was more significant in showing progression in patients with pulmonary emphysema. At the same time, 5 RSTS was found to be more effective in the progression follow-up of healthy patients.

Consistent with previous research, this study found that the $FEV_1/FVC$ ratio was not a reliable indicator of muscle strength or the severity of symptoms [6,10]. However, we found no link between $FEV_1$ and functional status (STS and 6 MWT) in pulmonary emphysema patients or healthy people. Our findings further confirmed that $FEV_1$ alone does not serve as a robust indicator of functional status in individuals without underlying health conditions. Therefore, as pulmonary emphasized in similar studies, it is impossible to have information about the function of the patients by looking at the values related to $FEV_1$ in our study. The best indicator refers to exercise tests [9,10,14]. This study evaluated that the 1 MSTS test was significantly more prominent in detecting sick people. The 5 RSTS test was significantly more prominent than the 6 MWT test in detecting healthy people.

FeNO is a marker of airway inflammation, commonly associated with allergic conditions, yet it also reflects underlying non-allergic inflammatory processes, pulmonary vascular responses, and reactions to environmental exposures. In fact, in a study showing the relationship with exercise, there is a significant increase in FeNO after exercise, and the reason for this is the increase in NO production in the body after acute and chronic exercise [20,31]. Additionally, in a study conducted on children with asthma, there was no significant increase in FENO before and after the pulmonary function test, postbronkodilator pulmonary function test [23]. In this study, patients with pulmonary emphysema exhibited a significantly greater change in FeNO levels before and after the 6-minute walk test—including post-bronchodilator measurements—compared to those undergoing the 1-minute or 5-repetition sit-to-stand tests. On the other hand, no statistically significant difference was seen among healthy participants. This can be evaluated as more effort is spent during the 6 MWT, especially in pulmonary emphysema patients. The lactic acidosis and increased nitric oxide levels in the muscles give a fatigue stimulus. This can be considered a negative stimulus in the comfort of the person. Therefore, it can be a step ahead of both STS tests with less effort. In addition, FENO levels are independent of age, and gender supports its safe use before and after these tests in pulmonary emphysema patients [32].

Pulmonary emphysema can cause severe limitations and inability in daily routine activities in people with pulmonary emphysema. As the disease advances, worsening airway obstruction

leads to symptoms like dyspnea and fatigue, with a progressive decline in overall respiratory function [33].

Currently, laboratory biomarkers such as blood eosinophil count and C-reactive protein (CRP) are frequently used in the clinical follow-up of patients with COPD. But these tests do not provide information about muscle condition and exercise capacity. Peripheral muscle weakness in patients with pulmonary emphysema is often a result of prolonged immobility and muscle atrophy, which together contribute to a decline in functional capacity [35]. In fact, due to this condition, there is performance limitation and cardiorespiratory deficiency with dyspnea and lower extremity muscle weakness [11]. Despite their average body weight, patients significantly decrease total muscle mass and atrophy-like changes.

In this study, we found that less effort and less fatigue in sit to stand tests despite the feeling of more fatigue due to lactic acidosis that may occur as a result of 6 MWT, which has already been shown by the magnetic resonance spectroscopy method that pulmonary emphysema patients develop lactic acidosis in a shorter time and against low fiber loads during exercise due to poor aerobic capacity in their muscles compared to typical cases and that this causes fatigue and exercise tolerance negatively [36]. For this reason, we can say that pulmonary emphysema patients generally lead an immobile and sedentary life and aim to protect themselves from respiratory distress in this way. In our study, as in similar studies, a significant decrease was found in quadriceps muscle strength measurements in the pulmonary emphysema group compared to the healthy population. In addition, the increase in the Borg dyspnea scale in participants after 6 MWT, 1 MSTS, and 5 RSTS compared to baseline may be a reason and indicator of the tendency to live sedentary life developed as a protection mechanism in pulmonary emphysema patients as in similar studies. This study found that both STS and 6 MWT test outcomes correlated with each other. Similar to the 6-minute walk test, sit-to-stand test outcomes showed a correlation with age, severity of dyspnea, and peripheral muscle strength in both patients with pulmonary emphysema and healthy individuals. These findings suggest that the three tests provide consistent and comparable results, indicating a level of agreement among them. Furthermore, we observed that the pulmonary emphysema group exhibited significantly greater cardiorespiratory stress, reductions in $SpO_2$, and elevations in FeNO levels following STS tests, in contrast to the responses observed after the 6 MWT and the alternative sit-to-stand protocols.

Quadriceps strength plays a critical role in facilitating knee mobility, which is essential for enabling elderly or physically limited individuals to rise from a seated position—thereby directly influencing STS test outcomes [37]. This study demonstrated that both the 1-minute and 5-repetition sit-to-stand tests were significantly associated with muscle strength, similar to the 6-minute walk test, in individuals with pulmonary emphysema as well as healthy participants, although these are strength tests as stated in the studies we mentioned [14,38,39].

Based on these findings, we suggest that both STS protocols may serve as useful tools in identifying peripheral muscle weakness and functional decline in individuals with pulmonary emphysema, in a manner comparable to the 6-minute walk test.

Among individuals with chronic airway obstruction, age and the severity of dyspnea have been identified as the most reliable predictors of reduced exercise performance, both of which closely relate to walking capacity [9,10]. This study, we found that dyspnea severity was directly proportional to age and gait at 6 MWT. These results show that both 1 MSTS and 5 RSTS cause less dyspnea and fewer respiratory symptoms in patients with pulmonary emphysema. One study identified a relationship between 6 MWT, desaturation, and heart rate [9]. A separate study demonstrated that, in patients with pulmonary emphysema, the 6-minute walk test led to a significant increase in heart rate and perceived dyspnea, along with a marked reduction in oxygen saturation by the end of the test [40]. Our study obtained similar results in patients with pulmonary emphysema due to 6 MWT. Both STSs are easier to perform and

produce less cardiac stress as they do not cause a significant decrease in heart rate saturation as in the 6 MWT.

Rising from a seated position is broadly acknowledged as a fundamental and routine component of daily functional activities [15]. Celli et al. showed that in some patients with COPD, the arm muscles are active during walking [37]. Such activity might trigger reflex stimulation of the respiratory centers, potentially resulting in uncoordinated breathing patterns and impaired gas exchange. When we compared all three tests in this study, we hypothesized that upper limb muscle activation might be influenced by patients' motivation and encouragement by researchers. However, in both STSs, unlike the 6 MWT, there is no arm activity, so the arm muscles are not active as in walking [14]. Therefore, it should be noted that STS may be a familiar form of exercise for our patients who are more sedentary than the normal population and may require less respiratory demand than 6 MWT. Since both STS tests were easier to influence patient response than the 6 MWT, both STSs demonstrated that exercise capacity in patients with pulmonary emphysema could be assessed more accurately and quickly than the 6 MWT.

Previous studies have shown that routine physical activities, including walking, are linked to temporary reductions in oxygen saturation among individuals with pulmonary emphysema [14,41]. In the current study while the 6-minute walk test led to oxygen desaturation in patients with pulmonary emphysema, the lack of desaturation observed during both STS protocols suggests that these tests may offer a more precise assessment of exercise capacity without inducing hypoxemia.

### Limitations

The study has a few limitations, which warrant consideration in the interpretation of the results. Firstly, although we included a broad range of potential predictors for poor 6 MWT performance in our model, some factors that could enhance predictive power were not included. These omitted factors include, for example, the amount of regularly taken medication, participation in rehabilitation programs, treatment durations, diffusion test results, and genetic phenotype measurements.

Secondly, repeated testing to assess the stability of 6 MWT and STS test performance over time was not conducted, and variability over time was not examined in this study.

Lastly, the limited number of female participants in this study necessitates a cautious interpretation of the findings related to women, as these results may not be fully representative of the broader female COPD population.

## Conclusion

This study is unique because it was conducted in patients with a pure pulmonary emphysema phenotype. Therefore, we concluded that both STSs could better determine functional status in both genders with pulmonary emphysema and with less effort as an alternative to the 6 MWT test. We also found that 1 MSTS was more sensitive than 6 MWT in detecting disease progression and 5 RSTS was more specific than 6 MWT in discriminating healthy subjects.

When the results were evaluated, we statistically determined that both STS showed functional status like 6 MWT in patients with pulmonary emphysema because they were hemodynamically less stressful, easier to perform, and more sensitive to the clinical status of the patient compared to 6 MWT. We also evaluated the 1 MWT as statistically more significant than the 6 MWT in showing progression in patients with 1 MWT and healthy patients with 5 RWT. Therefore, STS tests are sufficient to evaluate the progression of male and female pulmonary emphysema patients at the time of examination in polyclinic conditions such as our country, where patient density is high and physical facilities and technician problems are often encountered, without the need for technical personnel and a long intermediate corridor. The reason for obtaining similar findings in male and female genders is that both groups have similar structures in terms of height and weight, which explains the situation to us.

This may reduce the need for additional PFT and 6 MWTs for patients' evaluation, saving time, clinical resources, and staff workload. A

practical and rapid determination of functional capacity will be made.

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*Conflict of interest*

The authors confirm that there are no conflicts of interest associated with this study.

*Data availability statement*

The data used and analyzed during this research are available from the corresponding author upon reasonable request.

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